



Knowledge of Holocene hydro-climatic conditions in northern China from high temporal resolution stalagmites collected from Lianghua Cave

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Our understanding of hydro-climatic dynamics in the East Asian monsoon region during the Holocene was obstructed by very few absolutely dated and high temporally resolved proxy records in northern China. Here we present duplicated carbonate $\delta^{18}\text{O}$ records of six stalagmites with sub-decadal to multi-decadal temporal resolutions from Lianhua cave to reveal a detailed transition of the East Asian Summer Monsoon (EASM) intensity in northern China from 11.5 thousand years ago (hereafter, ka BP, before 1950 AD). Our composite records show that solar forcing dominated hydro-climatic changes, including an intensified monsoon at the Holocene Optimum from the end of Younger Dryas to 6.5 ka BP, and a subsequent multi-millennial weakening of monsoon intensity, that agree with cave records in central and southern China. However, the EASM has retreated southwards more rapidly than the Indian summer monsoon after ~ 6.5 ka BP, resulting in some rapid onset of dry conditions occurring at 4.0 ka BP in northern China, which is ~ 2000 years earlier than in central and southern China. This asynchrony may be related to the different regional responses among the coupling of the EASM, Indian summer monsoon, the solar forcing, and the differences in thermal forcing due to complex geographical configurations. In addition, a relative enrichment of 1‰ in our $\delta^{18}\text{O}$ data of Lianhua record from 9.5 to 8.1 ka BP shows that the Holocene Optimum was punctuated by a millennial-long weak monsoon interval, which is not registered among previous cave records in central and southern China. The freshwater-induced cold climate conditions in the North Atlantic region could create stronger East Asian winter monsoon and induce a weakened EASM and a southward shift of precipitation band in northern China. Therefore, it shall not be surprised that there are strong heterogeneities among regional hydro-climatic conditions across monsoonal China in the Holocene, given the complex interplay between external and internal forcing mechanisms over the entire Holocene.

Keywords: Cave Stalagmite; Northern China; East Asian Summer Monsoon; Holocene Optimum; Strong Heterogeneous Hydrological Conditions